Enhanced Condensation for Organic Rankine Cycle

3rd Quarterly Progress Report

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1. Back Ground

Generating electricity from low grade heat sources has attracted attention due to rising fuel price and increasing energy demand. The organic Rankine cycle (ORC) system is the most practical solution among technologies developed for low grade heat recovery. However, the efficiency of a typical small scale ORC is 10% or less. Most energy loss in the ORC is attributed to thermodynamically irreversible heat transfer processes occurring in its heat exchangers: the evaporator and condenser. In particular for waste heat recovery ORCs, economical success is mainly determined by effectiveness of the condenser because, while their heat source is provided at no cost, heat rejection accounts for most of operation cost. Almost half of total cost for operation and maintenance of an ORC system can stem from its condenser. We investigate and demonstrate heterogeneous condensing surfaces that potentially reduce the irreversibility during the condensation of organic fluids.

2. Progress Report

We have made progress during the reporting period (Aug 1 – Sept 30) and progress activities are described below.

Task 1: Model Development (Completed)

Task 2: Design and Construction of Testing Apparatus

During the previous reporting period, most of the construction of the testing apparatus had been completed. Since then, we assembled all the parts together and prepared the entire apparatus for the test running. A couple of runs of initials tests were conducted to figure out if there were any problems in the condenser system. We observed two issues, which needed immediate attention:

- The brittle glass wall of the heating chamber and
- Failure in drain of the condensate back to the heating chamber

<u>The glass wall of the heating chamber</u>

We chose borosilicate glass cylinder as wall for the heating chamber since it has low thermal conductivity and highly resistant to thermal shock. Also borosilicate glass was known to withstand high temperatures and pressures. When we first ran the test with full assembly of condenser the borosilicate glass was fine. After rectifying minor issues from the first test and when we started to run the second, we found out that the glass cracked at higher temperatures. After testing with new borosilicate glass and careful observation we found that the edges of the glass were chipped away at the contact of the aluminum discs. This is due to the brittleness of glass. The chipped away edges caused local stresses in the borosilicate glass. As a result at high temperatures the crack started because of the local stresses and then the crack propagated throughout the length of the cylinder. Consequently, the working fluid leaked through the crack.

We concluded that the glass cylinder without any gasket (which does not allow the edges of the glass cylinder to come in contact with metal, which avoids chipping) would not work for our experimental setup. Thus we had to choose a different wall material, which would replace borosilicate glass and still have the same optical properties and thermal properties and which should be less brittle than glass. The closest material that we found would suit our experimental setup was acrylic. Acrylic material has all the optic properties that glass have and is less prone to cracking. The test apparatus shown in the figure below is equipped with the new acrylic wall for the heating chamber.

<u>Condensate flow to the heating chamber</u>

After the working fluid was vaporized, the vapor would again condense by rejecting heat to the condenser. The condensate then flows back into the heating chamber through hoses. The whole set up was discussed in the previous report. When we ran the test after fixing issues with the borosilicate glass, we found out that the condensate failed to flow back into the heating chamber. The condensate filled up the condensing chamber since the condensate did not drain to the heating chamber. The condensing chamber was at high elevation than the heating chamber. The height difference would create a pressure difference, allowing for the circulation of the condensate. The condensate has the potential energy due to elevation in addition to the kinetic energy due to flow through pipes both of which would overcome the velocity of the vapor generating from the heating chamber. After careful observation we found out that the vapor did not allow the condensate to flow through the pipes.

For the condensate to flow to the heating chamber we needed to pump the condensate from condensing chamber to the heating chamber. In selection of a pipe, we considered the fact that the pressure difference between the two chambers should be very small and that the mass flow rate of the pump should be low enough that the pressure in the condenser is maintained at a constant pressure. A pump which satisfied this application has been installed as shown in the figure below.

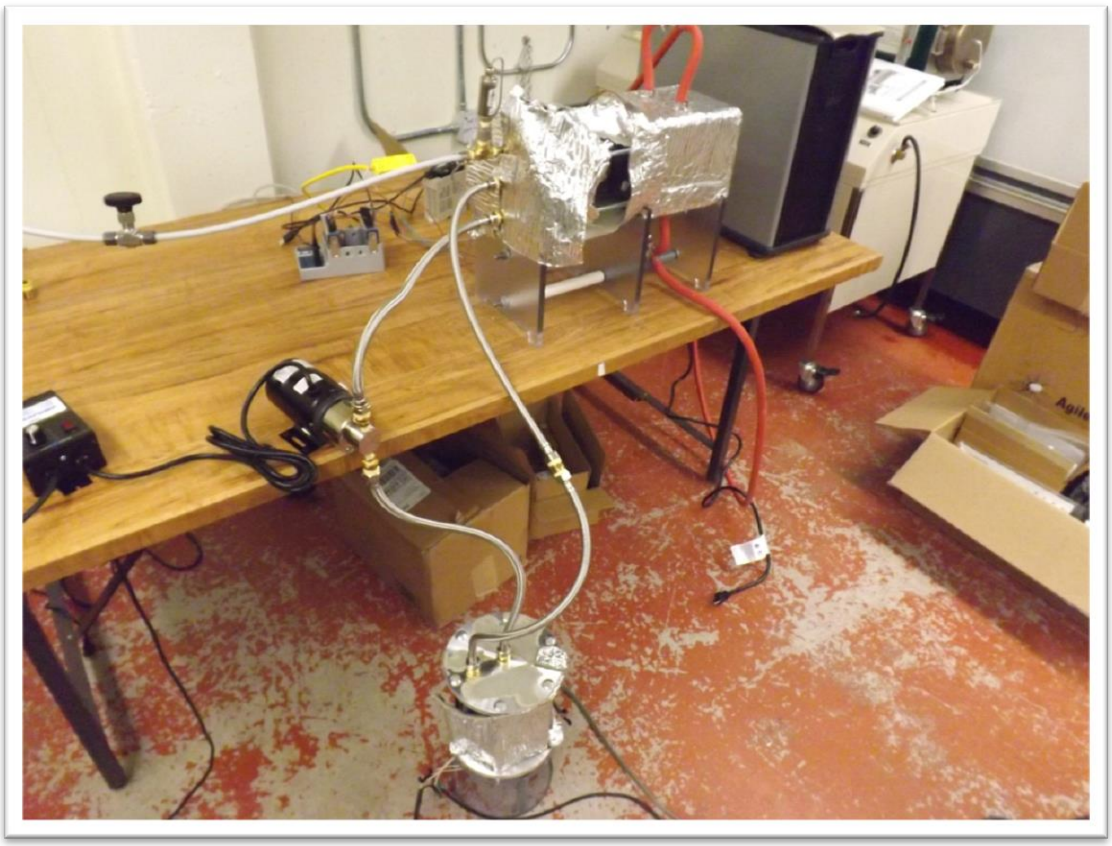

Figure 1: The condensation apparatus equipped with the acrylic heating chamber wall and the drain pump and its driver.

Task 3: Initial Performance Testing

Upon completion of Task 2 (Design and Construction of Testing Apparatus), we will begin running several sets of initial performance testing. It will include condensation of water on a non-treated copper surface and on a hydrophobic surface. During Task 3, we will select the type of organic fluids (working fluid).